BIOMECHANICAL ANKLE

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of co-pending U.S. patent application Ser. No. 348,284 filed Feb. 12, 1982, now U.S. Pat. No. 4,442,554, the disclosure of which is incorporated by reference as fully as if it appeared herein.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a prosthetic foot and more particularly to a prosthetic foot imitating the movement of the human foot about three axes.

2. Description of the Problem and Prior Art Solutions

The process of terrestrial locomotion in humans involves a complex interaction of muscular contractions around a variety of joints in the foot. The interaction of these complex movements gives the foot an ability to adapt to its external environment and permits travel with relative ease over a variety of terrestrial surroundings.

There are three primary categories of movement in the ankle and foot: dorsiflexion and plantar flexion, inversion and eversion, and lateral rotation.

Dorsiflexion and plantar flexion are defined as the upward-downward motion of the foot.in a plane perpendicular to the line of forward progression. Dorsiflexion is the movement of the foot upwardly and plantar flexion is the movement of the foot downwardly around an axis running between the bony protuberances of the ankle (hereinafter the "ankle axis"). Movement of the ankle in this plane is possible through a range of approximately 70°, 20° of dorsiflexion and 50° of plantarflexion.

Eversion is defined as the moving of the sole of the foot outwardly at the ankle joint while inversion is defined as the moving of the sole of the foot inwardly at the ankle joint. These movements take place around the subtalar axis, which is somewhat parallel to the line of forward progression. More precisely, the subtalar axis extends from the lateral aspect of the heel to the medial aspect of the sole adjacent the big toe. In terms of anatomic structure, the motion here described takes place in the subtalor joint of the ankle/foot.

Movement about the subtalor axis may be analogized to that found in an oblique hinge in which outward rotation of a vertical hinge member results in inward rotation of a horizontal hinge member. Similarly, inward rotation of an upper hinge member results in outward rotation of a lower hinge member. Anatomically, the inward rotation of the foot so that the sole faces inwardly (inversion) occurs as a result of bones in the lower leg being rotated outwardly around an axis running longitudinally through the leg. Outward rotation of the foot so that the sole faces outwardly (eversion) occurs as a result of the inward rotation of the bones in the lower leg about a longitudinal axis through the leg. The typical range of inversion is 20°, while a typical range of eversion is 5°. This aspect of movement in the ankle/foot complex gives an individual the ability to walk on uneven terrestial surfaces and slopes without difficulty.

The third type of movement in the ankle and foot is lateral rotation, also known as tibia torsion motion. This

action occurs through a transverse, oblique hinge action of the ankle and foot. Laterial rotation moves the foot through a vertical plane substantially parallel to the ground.

The complex interplay among the three categories of motion described above gives rise to the natural gait observed in terrestial locomotion in humans. The walking cycle begins when initial floor contact is made with, for example, the heel of the right foot. Progressive dorsiflexion occurs throughout the first 30% of the walking cycle until the right foot is substantially flat on the ground. Plantar flexion next occurs as the heel is lifted off the ground, such flexion reaching a maximum at 60% of the walking cycle at which time "liftoff" occurs and the right foot swings forward through a step. The process of plantar flexion-dorsiflexion here described continues through each successive step.

In addition to plantar flexion-dorsiflexion, the foot is also simultaneously experiencing inversion-eversion. The inversion-eversion movement causes initial floor contact to occur at the lateral aspect of the heel as heel contact of the right foot occurs. As plantar flexion progresses, the pressure on the sole shifts diagonally from the lateral aspect of the heel to the medial aspect of the sole adjacent the big toe just as liftoff occurs. More precisely, inversion occurs until approximately 40% of the walking cycle has been completed, at which time eversion is experienced to transfer weight to the medial aspect of the foot to prepare for liftoff and swinging of the leg through a step.

If the foot were only permitted to move through a horizontal plane (dorsiflexion-plantar flexion) and about the subtalar axis (inversion-eversion), the foot would be limited in its adaption to the variety of terrains over which locomotion could smoothly occur. It is fortunate, therefore, that the human foot is also provided with lateral rotation, or movement through a horizontal plane about an imaginary axis running vertically through the leg and heel. This third motion enhances the fluidity of locomotion by permitting the smooth transfer of weight through an arc running diaganolly across the sole from the outside rear heel to the inside of the sole adjacent the big toe.

It is therefore desirable that a biomechanical ankle be provided which will imitate all three of the basic movements of the ankle and foot described above.

PRIOR ART STATEMENT

Characterizing the closest prior art of which the applicant is aware, attention is invited to the following United States Patent Numbers:

Delp U.S. Pat. No. 4,306,320;
May U.S. Pat. No. 3,874,004;
Simonsson U.S. Pat. No. 2,098,067;
Peer U.S. Pat. No. 710,996;
Parmelee U.S. Pat. No. 37,637.
Dumelin U.S Pat. No. 2 368,917.

Delp is considered relevant since it shows a ball and socket joint which permits opposing wedges to be adjusted so as to selectively adjust the degree of arch in the sole of a prosthetic foot. This arrangement is designed to adapt the foot to shoes having heels of different heights. It does not, however, imitate the movement of the foot in the three aspects described above.

May discloses an artificial ankle joint which is suitable for patients who have undergone the Symes amputation. A sole plate is provided having posterior and